

# *XMM-Newton* Observation of Fe $K\alpha$ emission from a BAL QSO: Mrk 231

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## ABSTRACT

We present results from a 20 ksec *XMM-Newton* observation of Mrk 231. EPIC spectral data reveal strong line emission due to Fe  $K\alpha$ , which has rarely been detected in this class, as BAL QSOs are very faint in the X-ray band. The line energy is consistent with an origin in neutral Fe. The width of the line is equivalent to a velocity dispersion  $\sim 18,000 \text{ km s}^{-1}$  and thus the line may be attributed to transmission and/or reflection from a distribution of emitting clouds. If, instead, the line originates in the accretion disk then the line strength and flat X-ray continuum support some contribution from a reflected component, although the data disfavor a model where the hard X-ray band is purely reflected X-rays from a disk. The line parameters are similar to those obtained for the Fe  $K\alpha$  line detected in another BAL QSO, H1413 + 117.

*Subject headings:* galaxies: active – galaxies: individual (Mrk 231) – galaxies: nuclei – galaxies: Seyfert

## 1. Introduction - the BAL QSO phenomenon

The ejection of matter at moderate to high velocities appears to be a common phenomenon in Active Galactic Nuclei (AGN). Details of the accretion and ejection processes provide fundamental insight into the fueling of the AGN, and the effect of an active nucleus on its environment. Moderate velocity (hundreds of  $\text{km s}^{-1}$ ) outflows have been observed in many Seyfert 1 galaxies (e.g. Kaspi et al. 2002). Broad Absorption Line Quasars (BAL QSOs) are the high-velocity systems, showing blueshifted optical and UV absorption lines from resonant transitions of ionized species such as C IV, Si IV, N V and O VI. Fabian (1999) suggested that BAL QSOs are in an early evolutionary phase when the mass of gas around a black hole is beginning to get blown away to reveal a QSO.

The BAL absorption lines are thought to arise in radiatively-driven material along the line-of-sight, with outflow velocities in the range  $5000\text{--}30,000 \text{ km s}^{-1}$  (e.g. Turnshek et al. 1988). BAL QSOs

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comprise  $\sim 8\%$  of the high-luminosity QSOs (see Weyman 1997 for an overview). Models for BAL QSOs seek to explain how gas gets accelerated to the observed velocities. Suggestions have included a scenario where gas and radiation pressure lift material from the photosphere of the accretion disk and this gas is illuminated by radiation from the inner disk/corona (Murray et al. 1995). That nuclear photon flux then accelerates the wind outwards. As the inner edge of the wind is thought to be quite close to the central source, some “shielding” gas has been invoked to prevent the wind material becoming stripped, and difficult to drive. This gas is thought to be highly-ionized and have column density in the range  $N_H = 10^{22} - 10^{24} \text{cm}^{-2}$ . Proga et al. (2000) found that a layer of shielding gas arises naturally in their models for BAL winds. An alternative suggestion is that the outflow consists of dense clouds that are magnetically confined and that have small filling factor (Arav, Li & Begelman 1994).

Constraints to date on the BAL gas location and mass-loss rates have been based on the UV and optical data. X-rays may be the key to understanding BAL QSOs as they offer the opportunity to probe closer to the nucleus than studies in the optical and UV bands. Interesting X-ray results have recently emerged with detection of some broad absorption features from the lensed QSO, APM 082769+5255 (Chartas et al. 2002), indicating an origin in gas components outflowing at  $\sim 0.2 - 0.4c$ . However, BAL QSOs are very faint, and detection of significant spectral features in the X-ray band has been rare to date. For example, while Fe  $K\alpha$  emission is commonly seen in Seyfert 1 galaxies (e.g. Nandra et al. 1997) and valued as an indicator of conditions very close to the black hole, this line has been detected in just a few BAL QSOs, e.g. the gravitationally-lensed ‘Cloverleaf’ QSO, H1413+117 (Oshima et al. 2001). Here we report on a brief *XMM-Newton* (hereafter *XMM*) observation of the BAL QSO Mrk 231, yielding a rare detection of an Fe  $K\alpha$  emission line.

## 2. The Properties of Mrk 231

Mrk 231 ( $z=0.042$ ) is an ultraluminous infrared galaxy (ULIRG) and one of the strongest known FeII emitters. Furthermore, Mrk 231 has one of the highest bolometric luminosities in the local ( $z < 0.1$ ) universe with  $L_{8-1000\mu m} \sim 4 \times 10^{12} L_\odot$  and  $L_{BOL} > 10^{46} \text{erg s}^{-1}$  (Soifer et al. 1987). Bryant & Scoville (1996) find that starburst activity can only account for 40% of the IR luminosity in Mrk 231, an active nucleus appears to provide the rest of the energy. Another extreme property of Mrk 231 is its high polarization,  $\sim 20\%$  at  $2800 \text{\AA}$  (e.g. Smith et al. 1995), most likely due to scattering by dust. Broad optical emission lines are observed similar to those defining the Seyfert 1 class. However, no narrow emission lines are seen except for O[II]  $\lambda 3727$ . The absence of narrow emission lines is sometimes observed in quasi-stellar objects (QSOs) but rarely in Seyfert galaxies, this, and the high bolometric luminosity of Mrk 231 supported the idea that the nucleus of this source is similar to a QSO. This O[II] emission line is consistent with production in gas which is ionized by hot young stars (Smith et al. 1995) rather than by ultraviolet radiation from the nucleus. This possibility seems attractive since the nuclear UV, extreme-UV and soft X-ray photons are likely to be heavily attenuated by the dense circumnuclear absorber, i.e. the narrow-line gas may not receive ionizing radiation.

Boroson et al. (1991), Rudy et al. (1985) and Rupke et al. (2002) are among those discussing several distinguishable Broad Absorption Line (BAL) systems evident in optical and UV observations of Mrk 231. The most prominent is defined by NaI, CaII and HeI lines originating in gas with an outflow velocity  $\sim 4200 \text{ km s}^{-1}$  relative to the line emission seen in the source. Other systems appear and disappear between observing epochs, showing velocities from  $\sim 200 \text{ km s}^{-1}$  inflow to  $\sim 8000 \text{ km s}^{-1}$  outflow (e.g. Boroson et al. 1991; Kollatschny, Dietrich & Hagan 1992; Forster et al. 1995). Rudy et al. (1985) showed that the shapes of absorption features and velocities in the absorbing gas systems of Mrk 231 are the same as those observed in BAL QSOs and suggested the gas is probably accelerated by the same mechanism. Nevertheless, the nature of the absorbing systems in Mrk 231 continued to be debated. The width of the CIV resonance line is used as a key indicator of the BAL nature of an AGN (Weyman 1997). Heavy reddening has made that line width difficult to constrain in Mrk 231 until an *HST* spectrum settled the case in favor of a BAL QSO designation (Gallagher et al. 2002; hereafter G02). Most BAL systems are dominated by high-ionization species, only  $\sim 15\%$  have absorption by low-ionization systems such as MgII $\lambda\lambda$ 2796 and 2803, AlII $\lambda\lambda$ 1671, AlIII $\lambda\lambda$ 1855 and 1863 and CII $\lambda\lambda$ 1335 (Voit, Weymann & Korista 1993). In addition to these low-ionization systems, Mrk 231 shows even rarer absorption lines, such as NaID, HeI $\lambda$ 3889 and MgI $\lambda$ 2853. While Mrk 231 does show some of the high-ionization systems (G02) it is dominated by the low-ionization systems; the MgII absorption in particular, places Mrk 231 into the so-called LoBAL subclass of low-ionization BAL QSOs.

## 2.1. Previous X-ray Observations of Mrk 231

The *ROSAT* High Resolution Instrument (HRI) showed extended soft X-ray emission consistent with the extent of the host galaxy ( $\sim 10''$ ; Turner 1999), confirmed using *Chandra* (G02). An early *ASCA* observation (Iwasawa 1999; Turner 1999) showed a flat spectrum but with insufficient counts to distinguish between absorption or reflection models. In this paper we use the term “reflection” to refer to reprocessing of photons via Compton scattering and fluorescence by material which is optically-thick to electron scattering. We use the term “scattering” to refer to the case where the optical depth to electrons is  $0 < \tau < 1$ . A longer *ASCA* observation (Maloney & Reynolds 2000; hereafter MR) suggested the X-ray spectrum to be dominated by reflected plus scattered nuclear emission with a large absorbing column in the line-of-sight. Thus MR suggested a Seyfert 2 type geometry and orientation for Mrk 231, with the accretion-disk system surrounded by a shell of absorbing gas  $N_H \sim 3 \times 10^{22} \text{ cm}^{-2}$  which covers direct and reflected/scattered components. The shell may block ionizing radiation from the optical narrow-line region, while allowing hard X-rays to penetrate. G02 find significant variability in the hard X-ray flux, and suggested nuclear X-rays are hidden by a Compton-thick cloud (Fig 12 of G02) existing on size-scales  $< 10^{15} \text{ cm}$ , while scattered X-rays from multiple lines-of-sight reach the observer. In the context of the MR model the hard X-rays could vary if the reprocessor were suitably small. This may be reasonable for a source like Mrk 231, radiating at a large fraction of the Eddington luminosity, as the inner disk may puff up into a funnel (Rees 1984) yielding a reflector surface consistent with the size implied by variability in this case. Smith et al. (1995) suggest there may be a superposition of two polarized components

in Mrk 231, supporting the importance of scattering in this system.

### 3. The XMM-Newton Observation

#### 3.1. Data Reduction

An *XMM* observation of Mrk 231 was performed starting 2001 June 7 UT 13:10:24 with an exposure time of  $\sim 22$  ks. Here we present analysis of the archived *XMM* data from that observation. *EPIC* data were processed using SASS 5.4. *EPIC* pn and MOS data utilized the medium filter and the prime full window. The *EPIC* data were screened to remove hot and bad pixels, and some brief periods of high background counts. Instrument patterns 0 – 12 (MOS) and 0 – 4 (pn) were selected. The screening criteria resulted in an effective exposure of 21.4 ks for the MOS and pn data. The background-subtracted count rates were  $0.0391 \pm 0.0014$  (MOS1),  $0.0389 \pm 0.0014$  (MOS2) and  $0.130 \pm 0.0028$  (pn) over the 0.3–10.0 keV band. Spectra and time series were extracted from a cell of radius  $\sim 30''$  centered on the source. Background spectra were extracted from nearby, source-free regions of MOS and pn, the background was  $\sim 6\%$  of the source count rate. Unfortunately this brief exposure accumulated only 400 source counts in the combined arms of the RGS data, insufficient for spectral analysis.

#### 3.2. EPIC Results

*XMM* data showed Mrk 231 to have an observed flux  $F_{2-10 \text{ keV}} \sim 6.2 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$ , during the June 2001 observation, corresponding to an observed luminosity  $L_{2-10 \text{ keV}} \sim 2 \times 10^{42} \text{ erg s}^{-1}$  (assuming  $H_0 = 75 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ,  $q_0 = 0.5$  throughout). The 2 - 8 keV flux ( $5 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$ ) is consistent with that reported by G02. We found no significant variations in X-ray flux within this short *XMM* exposure.

The overall spectral shape is complex. Several previous papers have discussed the difficulty in distinguishing between models where the active nucleus is covered by a patchy and/or ionized absorber (Iwasawa 1999; Turner 1999) and those where the spectrum is dominated by a reflected component (MR). This *XMM* exposure is brief and the data do not allow us to determine the precise contributions of reflected and absorbed continua to the overall spectrum. However, progress is possible as the pn spectrum shows two prominent emission lines (Fig 1) plus emission consistent with a blend of lines from the (previously suspected) thermal component peaking between 0.5 - 1 keV (Iwasawa 1999; Turner 1999; Gallagher et al. 2002, MR). *EPIC* data show some evidence for absorption-like features at  $\sim 1.1$ , 1.6 and  $\sim 2.4$  keV. The latter appears only in pn data and is probably an instrumental effect. For the others, the low S/N combined with the modest energy resolution leads to ambiguity between emission and absorption features. These may be absorption features due to Fe, but these data do not allow an unambiguous determination.

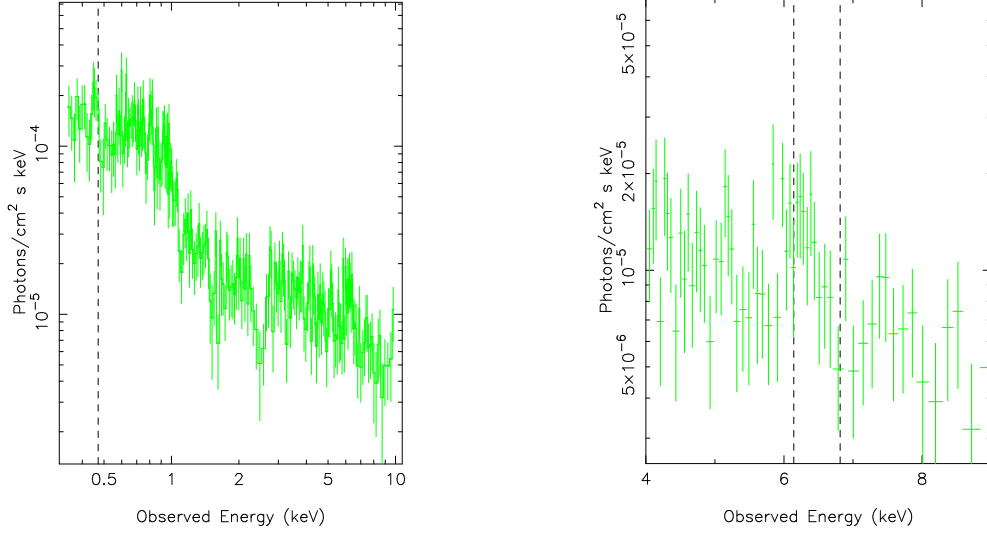


Fig. 1.— *Left: The EPIC pn spectrum of Mrk 231 from a 20 ksec exposure with XMM. A large flux of lines is also evident between 0.5 - 1 keV. A sharp dip just above 2 keV does not show up in MOS data and is likely to be an artifact of the instrument. The dashed vertical line shows where we would expect the C VI RRC feature, at the redshift of the host galaxy. The right panel shows a close-up of the Fe K $\alpha$  line. Dashed lines denote the expected placement of a line emitted at 6.4 keV and an edge at 7.1 keV, observed at the redshift of the host galaxy.*

One of the most obvious features in the pn data is immediately identified with emission from the K-shell of Fe. The pn detects 30 counts in the line during this exposure. The MOS spectra have far fewer counts and the line is not significantly detected in those (although the data are consistent with the pn results). Thus we used only the pn data to derive the line parameters given below. Detection of an Fe line in the EPIC spectrum from Mrk 231 is also reported within the analysis of a sample of Ultra-Luminous Infrared Galaxies performed by Franceschini et al. (2003).

First we fit the Fe K $\alpha$  line relative to a ‘local’ continuum parameterized as a powerlaw between 4 – 9 keV, absorbed by the galactic line-of-sight column ( $N_H = 1.27 \times 10^{20} \text{ cm}^{-2}$ ). This yielded  $\Gamma \sim 1.01^{+0.39}_{-0.38}$ , indicative of complex absorption and/or a contribution from reflection, as previously found for this source. We measured an observed-energy for the emission line  $E = 6.23 \pm 0.12 \text{ keV}$ , corresponding to a rest-energy  $E = 6.49 \pm 0.12 \text{ keV}$  correcting for the systemic velocity of the host galaxy. The line width was  $\sigma = 0.17^{+0.12}_{-0.11} \text{ keV}$  with flux  $n = 3.85^{+2.11}_{-1.86} \times 10^{-6} \text{ photons cm}^{-2} \text{ s}^{-1}$  and the luminosity in the line was  $L_{FeK} = 1.3 \times 10^{41} \text{ erg s}^{-1}$ . The lower limit of  $\sigma = 60 \text{ eV}$  means the Fe K $\alpha$  line has a significant breadth. (Errors are 90% confidence.) The line equivalent width is  $\sim 450^{+229}_{-204} \text{ eV}$  relative to the local continuum. For comparison the spectral resolution of the pn at 6.4 keV is  $\sigma \sim 50 \text{ eV}$ . Fig 1 shows the data compared to lines denoting the expected observed energies of an emission line from neutral Fe, along with the energy of the Fe K edge which would arise in the same gas, both assumed to be observed at the redshift of the host galaxy. While a dip is evident at the energy where an edge is expected, addition of an edge did not improve the fit significantly.

For comparison, we fit the line relative to a “pure reflection” model for data in the 2 - 10 keV band

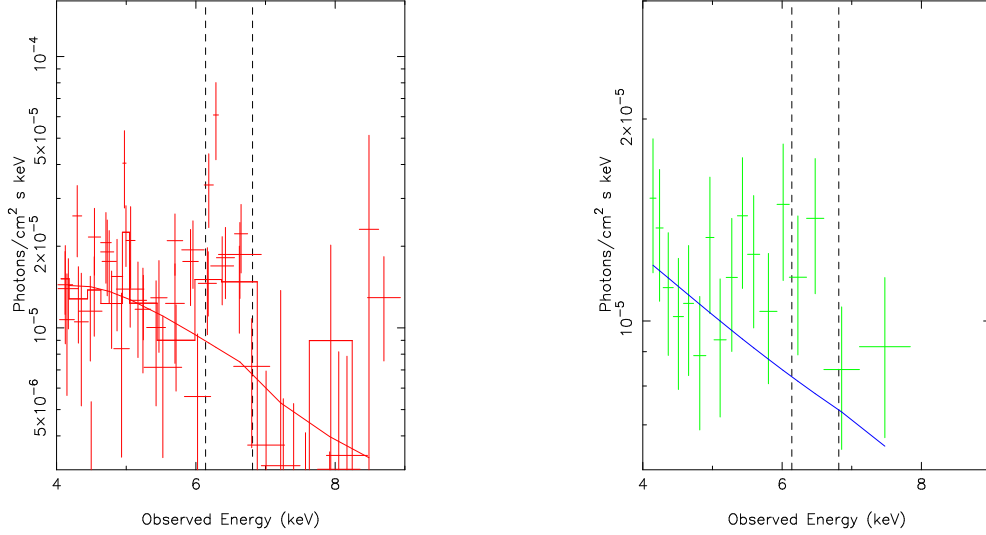


Fig. 2.— The left-hand panel the Fe  $K\alpha$  line in the combined instruments provided by ASCA data, the dashed vertical lines represent the energies of a line at 6.4 keV and an edge at 7.1 keV observed at the redshift of the host galaxy. The right-hand panel shows data in the same regime from our analysis of the archived ACIS observation of 2000 October. The Fe  $K\alpha$  line is evident in both datasets, and the flux is consistent with that found by the *pn*.

(as suggested by MR). This fit utilized the PEXRAV model (Magdziarz & Zdziarski 1995) from XSPEC. Fits were attempted assuming disk inclination angles of  $45^\circ$  and  $0^\circ$  (face-on). The (unseen) powerlaw was assumed to be  $\Gamma = 2.0$  and to turn-over at 100 keV. Fits using the former disk orientation gave  $\chi^2 = 103/97$  *dof* and a line equivalent width  $EW = 202^{+208}_{-202}$  eV relative to the reflected continuum, while a face-on disk yielded  $\chi^2 = 103/97$  *dof*,  $EW = 139^{+221}_{-139}$ . The best-fit equivalent width in either case is lower than that found relative to the absorbed powerlaw because the edge in the reflected continuum contributes to the curvature just above 6.4 keV, and so fewer photons are attributed to the line. In these two (pure reflection) disk models the best-fit line strength is about 10% of the strength expected, relative to the reflected continuum (George & Fabian 1991). Thus the line strength is low compared to the model in this picture. As the discrepancy is in the ratio of reflected line to reflected continuum, we can extend this result to a range of geometries. The line is too weak relative to the reflected continuum if reflection occurs from either a disk or a distribution of clouds.

Alternative fits were attempted, which utilized both transmitted and reflected components, with an unconstrained absorber covering both. First we considered the face-on disk. We fixed the reflection to that expected from a flat disk illuminated by an isotropic source ( $R = 1$  in PEXRAV). This yielded  $\chi^2 = 93/97$  *dof* with a flat photon index  $\Gamma = 1.14^{+0.48}_{-0.75}$ ,  $N_H = 2.69^{+2.41}_{-1.57} \times 10^{22}$  cm $^{-2}$ , indicating additional, but undeterminable complexity to the absorber. We obtained similar results for a disk at  $45^\circ$ , with  $\chi^2 = 93/97$  *dof*,  $\Gamma = 1.14^{+0.47}_{-0.74}$ ,  $N_H = 2.71^{+2.40}_{-1.96} \times 10^{22}$  cm $^{-2}$ . Fixing, instead, the photon index at  $\Gamma = 2$  yielded  $R \sim 10$  for both disk orientations, equivalent to the ‘pure reflection’ solutions, above.

To confirm the presence of the Fe line, and look for flux variability we reduced the long archival

observation by *ASCA*, from 1999 November 10-12. Data reduction followed the methods outlined for the Tartarus database (Turner et al. 2001). The *ASCA* spectral data were fit using all four instruments, and the spectrum confirms the presence of the Fe line (Fig 2). The spectrum was modeled constraining photon index, absorption, line energy and line width to match the values derived from the *XMM* data. This produced a good fit, with continuum flux  $F_{2-10 \text{ keV}} \sim 7.5 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$  and line flux  $n = 5.76_{-2.78}^{+2.91} \times 10^{-6} \text{ photons cm}^{-2} \text{ s}^{-1}$ .

We also reduced the archived ACIS data from 2000 October 19-20, originally reported by G02 (Fig 2). Extracting ACIS CCD spectra of Mrk 231 we fit the data using the same continuum and line model used for the *XMM* and *ASCA* spectra, leaving only line and continuum normalizations free. This model yielded a line flux  $n = 2.48_{-2.25}^{+2.26} \times 10^{-6} \text{ photons cm}^{-2} \text{ s}^{-1}$ . The differences in line flux are not significant and so the data show the line flux to be consistent with a constant value over a baseline of 1.5 years.

Turning to the soft X-ray band. Previous PSPC (Turner 1999) and *Chandra* ACIS data (G02) allowed limited spatially-resolved spectroscopy which provided two-temperature thermal models for the extended soft emission. While previous models account for the approximate flux in the soft band, they fail to produce some observed features such as the relatively isolated peak evident at  $0.471 \pm 0.03 \text{ keV}$  (Fig 1). Correcting for the redshift of the host galaxy we obtain a rest-energy  $0.490 \text{ keV}$ , nominally consistent with Cvi RRC  $0.492 \text{ keV}$ , although most of the line flux lies slightly redward of this energy (Fig 1). Confirmation of Cvi RRC would be interesting as the width would constrain temperature and excitation mechanism for the gas.

## 4. Discussion

A brief *XMM* observation of Mrk 231 has revealed a rare detection of Fe  $K\alpha$  from a BAL QSO. The presence of strong Fe  $K\alpha$  emission dispels any remaining doubt as to the presence of an active nucleus at the heart of Mrk 231. The existence of this line is confirmed by analysis of archived *ASCA* and *ACIS* data, and the line flux is consistent with a constant value between all datasets, covering a baseline of  $\sim 1.5$  years. The luminosity in the line is  $L_{Fe} \sim 10^{41} \text{ erg s}^{-1}$  which is typical of the Fe  $K\alpha$  luminosities observed in Seyfert 1 and 2 galaxies (e.g. Nandra et al. 1997; Turner et al. 1997). Assuming a nuclear system with an intrinsic luminosity in the Seyfert 1 range, the luminosity of the line would disfavor any model where we are seeing the line via scattering from optically-thin gas, which typically scatters only a few percent of nuclear emission into our line-of-sight in Seyfert 2 galaxies. The other alternative is that we see only a few percent of the line flux, which happens to come out to a line luminosity typical of Seyfert 1 galaxies. In this case the nuclear luminosity would just have to be a factor 50 or so higher than a Seyfert nucleus. Different analyses have yielded a wide range of inferred nuclear luminosities for Mrk 231, including an estimate at  $2 \times 10^{44} \text{ erg s}^{-1}$  (MR) which encompasses the latter possibility. The high equivalent width of the line, and the flat continuum shape are reminiscent of the properties of H1413 + 117 (Oshima et al. 2001). A line of this equivalent width could be produced from shell of gas  $N_H \sim 3 \times 10^{23} \text{ cm}^{-2}$  (Leahy & Creighton

1993). This column is consistent with that found when the X-ray spectrum is fit with a powerlaw, partially-covered by cool gas (Turner 1999). The line is too strong to be produced by scattering from a shell with  $N_H \sim \text{few} \times 10^{22} \text{cm}^{-2}$ , as suggested to cover the central regions (MR).

We turn now to the line energy. We consider the possibility that the line arises from neutral Fe. If so, there is no systematic velocity shift for the emitting gas. While the data disfavor models where we preferentially observe one side of a flow system, the line breadth is equivalent to a velocity-width of  $18500_{-12000}^{+13000} \text{ km s}^{-1}$ . The geometry of the emitting gas remains unconstrained, it could be anything from a spherical distribution or ring of clouds to the conical BAL flow, so long as we see contributions from both sides (as the line peak is not shifted). A specific model which fits this general picture is that of Arav, Li & Begelman (1994), where the line would arise in dense clouds with a small filling factor. The Fe  $K\alpha$  emission in H1413 + 117 (Oshima et al. 2001; Gallagher et al. 2002b) was also found to be consistent with an origin in neutral gas. In that case, emission from the BAL flow was used to explain the line, with the width suggesting a flow velocity of  $12,000 \text{ km s}^{-1}$ .

An alternative is that the line is produced in the accretion disk and that the broadening can be attributed to strong gravity, as it is in the spectra of Seyfert type AGN, where there are no high-velocity BAL flows. Of course the line width observed here is rather modest compared to the distortion observed in Seyfert profiles. The equivalent width of the line is  $\sim 450 \text{ eV}$ , about twice that expected from a source isotropically illuminating a flat disk (George & Fabian 1991), assuming we see both the primary and the reflected components. This may infer the reprocessor sees more of the illuminating flux than the observer does, or that there is a lag between primary and reprocessed spectra. An alternative explanation of the line strength is that the Fe abundance is very high in BAL QSOs, as expected if these are young systems (Hamann & Ferland 1999).

However, fits assuming we see only the reflected spectrum in the 2 - 10 keV band (i.e. the primary continuum is hidden) show the Fe line has just 10% of the strength expected, relative to the reflected continuum. This supports the case for some contribution from the primary continuum in the hard X-ray regime and thus disfavors pure reflection models, whether reflection occurs from a disk or from a distribution of clouds.

Of course, the breadth of the line could be due simply to Compton scattering of line photons in material along the line-of-sight, as discussed during the early days of Fe  $K\alpha$  observations from Seyfert 1 galaxies (e.g. Mushotzky et al. 1995). If so, the lack of shift to the peak indicates the opacity of that gas is low, while the upper limit on line width,  $\sigma$ , constrains the gas to  $kT < 0.5 \text{ keV}$  (using  $\Delta E/E = \sqrt{2kT/mc^2}$ ), following Mushotzky et al. 1995).

Finally, it is impossible to rule out emission from a higher energy, redshifted down to  $6.49 \text{ keV}$ . A velocity of  $24,000 \text{ km s}^{-1}$  is possible if the line is from recombination in H-like Fe. However, if the gas were highly ionized we would most likely see emission from both He-like and H-like Fe (and the observed feature would have to be a blend of these two). Further, it seems unlikely H1413 + 117 and Mrk 231 would both show single broad lines consistent with  $6.4 \text{ keV}$  by this conspiracy. Thus we favor an origin in neutral gas.



## 5. Acknowledgements

We are grateful to the *XMM* guest observer support team who provided useful input regarding the analysis of these data. We thank Ian George for useful comments. T.J. Turner acknowledges support from NASA grant NAG5-7538.

## REFERENCES

- Arav, N., Li, Z. Y., Begelman, M. C., 1994, ApJ, 432, 62
- Boroson, T.A., Meyers, K. A., Morris, S. L., Persson, S. E., 1991, ApJ, 370, L19
- Bryant, P.M., Scoville, N.Z. 1996, ApJ, 457, 678
- Chartas, G., Brandt, W. N., Gallagher, S. C., Garmire, G. P., 2002, ApJ, 579, 169
- Fabian, A. C., 1999, MNRAS, 308, 39
- Forster, K., Rich, R. M., McCarthy, J. K., 1995, ApJ, 450, 74
- Franceschini, A., et al., 2003, astro-ph/0304529
- Gallagher, S.C., Brandt, W.N., Chartas, G., Garmire, G. P., Sambruna, R. M., 2002 (G02) ApJ569, 655
- Gallagher, S.C., Brandt, W.N., Chartas, G., Garmire, G. P. 2002b, ApJ567, 37
- George, I. M. & Fabian, A. C., 1991, MNRAS, 249, 351
- Hamann, F, Ferland, G. 1999, ARA&A 37, 487
- Iwasawa, K. 1999, MNRAS 302, 96
- Kaspi, S. et al. 2001, ApJ, 574, 643
- Kollatschny, W., Dietrich, M., Hagan, H., 1992, ApJ, 264, L5
- Leahy, D. A., Creighton, J., 1993, MNRAS, 263, 314
- Magdziarz, P., Zdziarski, A. A., 1995, MNRAS, 273, 837
- Maloney, P. R., Reynolds, C. S., 2000 (MR) ApJ 545, 23
- Murray, N., Chiang, J., Grossman, S. A., Voit, G. M., 1995, ApJ, 451, 498
- Mushotzky, R. F., Fabian, A. C., Iwasawa, K., Kunieda, H., Matsuoka, M., Nandra, K., Tanaka, Y., 1995, MNRAS, 272, 9
- Nandra, K., George, I. M., Mushotzky, R. F., Turner, T. J., Yaqoob, T., 1997, ApJ, 477, 602

- Oshima, T., et al. 2001, ApJ, 563, L103
- Proga, D., Stone, J. M., Kallman, T. R., 2000, ApJ, 543, 686
- Rees, M.J., 1984, ARAA, 22, 471
- Rudy, R.J., Stocke, J. T., Foltz, C. B., 1985, ApJ, 288, 531
- Rupke, D. S., Veilleux, S., Sanders, D. B., 2002, ApJ 570, 588
- Soifer, B.T., Sanders, D. B., Madore, B. F., Neugebauer, G., Danielson, G. E., Elias, J. H., Lonsdale, C. J., Rice, R. W., 1987 ApJ, 320, 238
- Smith, P.S., Schmidt, D. G., Allen, R. G., Angel, J. R. P., 1995, ApJ, 444, 146
- Turner, T.J., George, I. M., Nandra, K., Mushotzky, R. F., 1997, ApJS, 113, 23
- Turner, T.J. 1999, ApJ 511, 142
- Turner, T.J., Nandra, K., Turcan, D., George, I. M., in “X-ray Astronomy: stellar endpoints, AGN and the diffuse X-ray background”. Ed. N. E. White, G. Malaguti, G.G.C. Palumbo, 2001, Melville, NY, AIP, 599, 1041.
- Turnshek, D. A., Grillmair, C. J., Foltz, C. B. & Weyman, R. J., 1988, ApJ, 325, 651
- Voit, G. M., Weymann, R. J., Korista, K. T., 1993, ApJS, 88, 357
- Weyman, R.J., 1997 in ASP Conf. Ser. V.128